BROWN

The design and construction of a projection oscillograph

Electrical Engineering

B. S.

1910

THE DESIGN AND CONSTRUCTION

OF

A PROJECTION OSCILLOGRAPH

BY

BRIGGS O. BROWN

THESIS

FOR THE

DEGREE OF BACHELOR OF SCIENCE

IN

ELECTRICAL ENGINEERING

COLLEGE OF ENGINEERING
UNIVERSITY OF ILLINOIS

PRESENTED JUNE 1908

UNIVERSITY OF ILLINOIS

June 1, 1908

THIS IS TO CERTIFY THAT THE THESIS PREPARED UNDER MY SUPERVISION BY

BRIGGS ODD BROWN

ENTITLED THE DESIGN AND CONSTRUCTION OF A PROJECTION OSCILLOGRAPH

IS APPROVED BY ME AS FULFILLING THIS PART OF THE REQUIREMENTS FOR THE

DEGREE OF Bachelor of Science in Electrical Engineering

J M Bryant
Instructor in Charge.

APPROVED: Morgan Brooks

HEAD OF DEPARTMENT OF Electrical Engineering

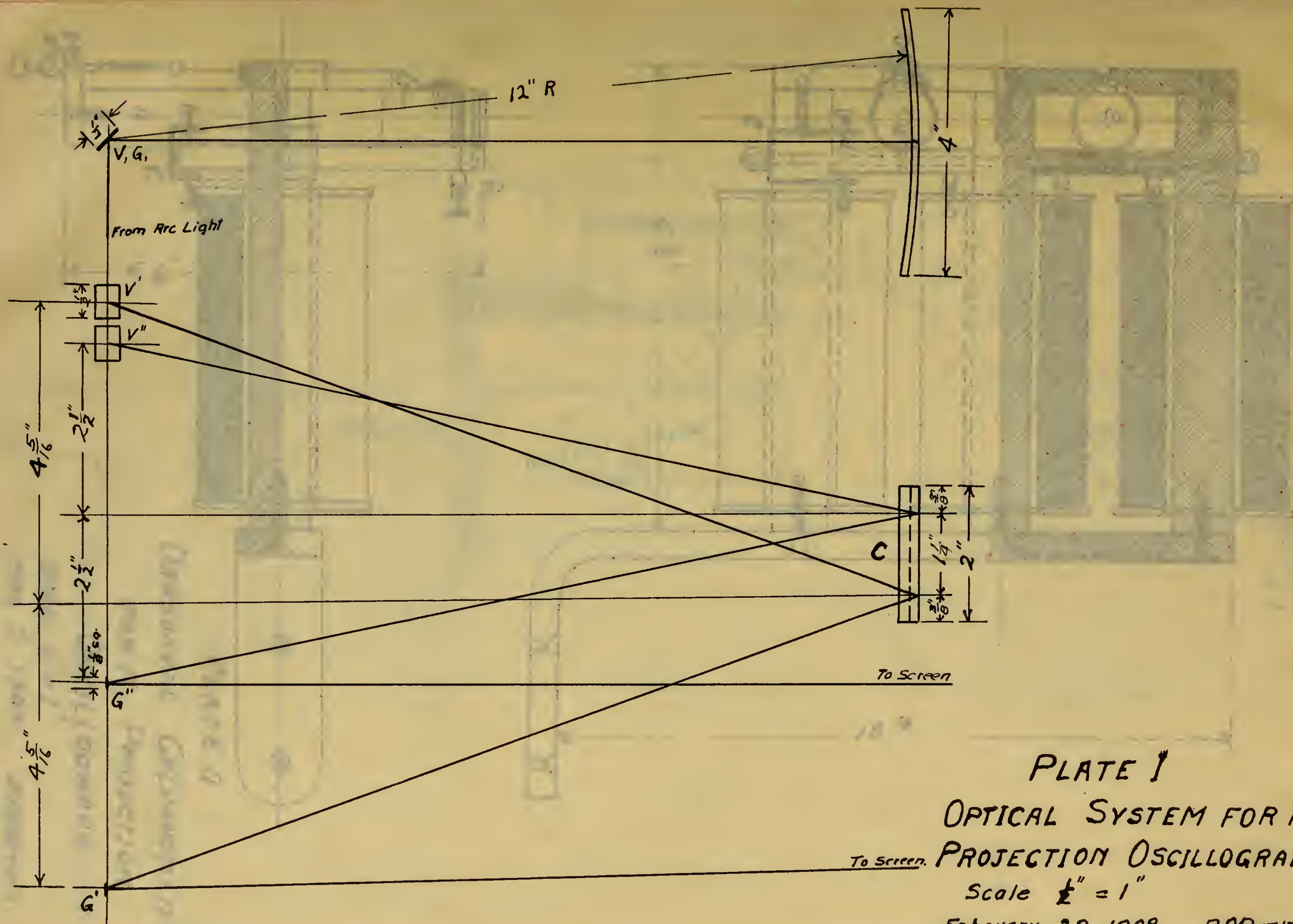

PLATE I

OPTICAL SYSTEM FOR A PROJECTION OSCILLOGRAPH

Scale $\frac{1}{4}$" = 1"

February 28, 1908. B.O.Brown

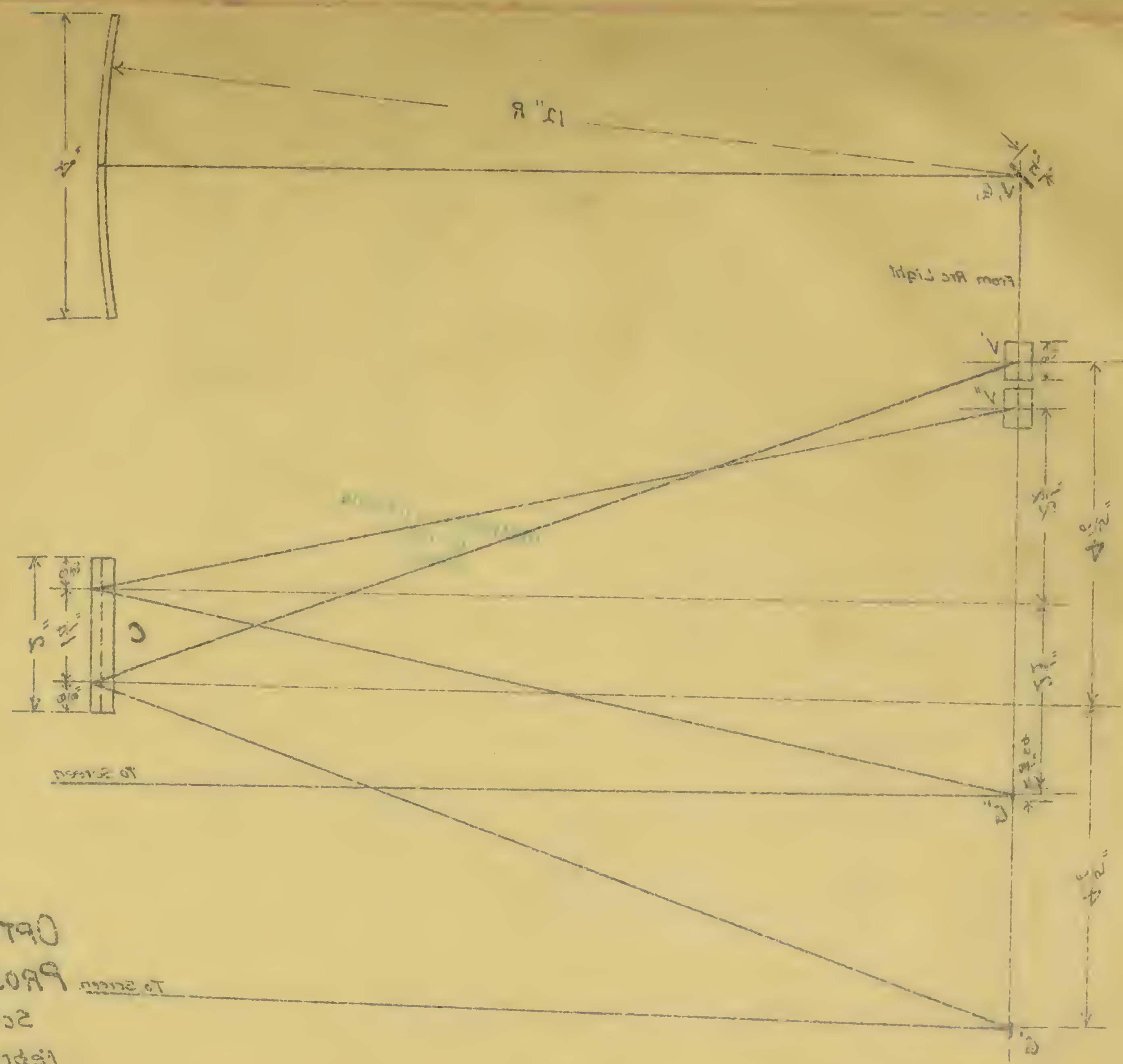

PLATE I

OPTICAL SYSTEM FOR A PROJECTION OSCILLOGRAPH

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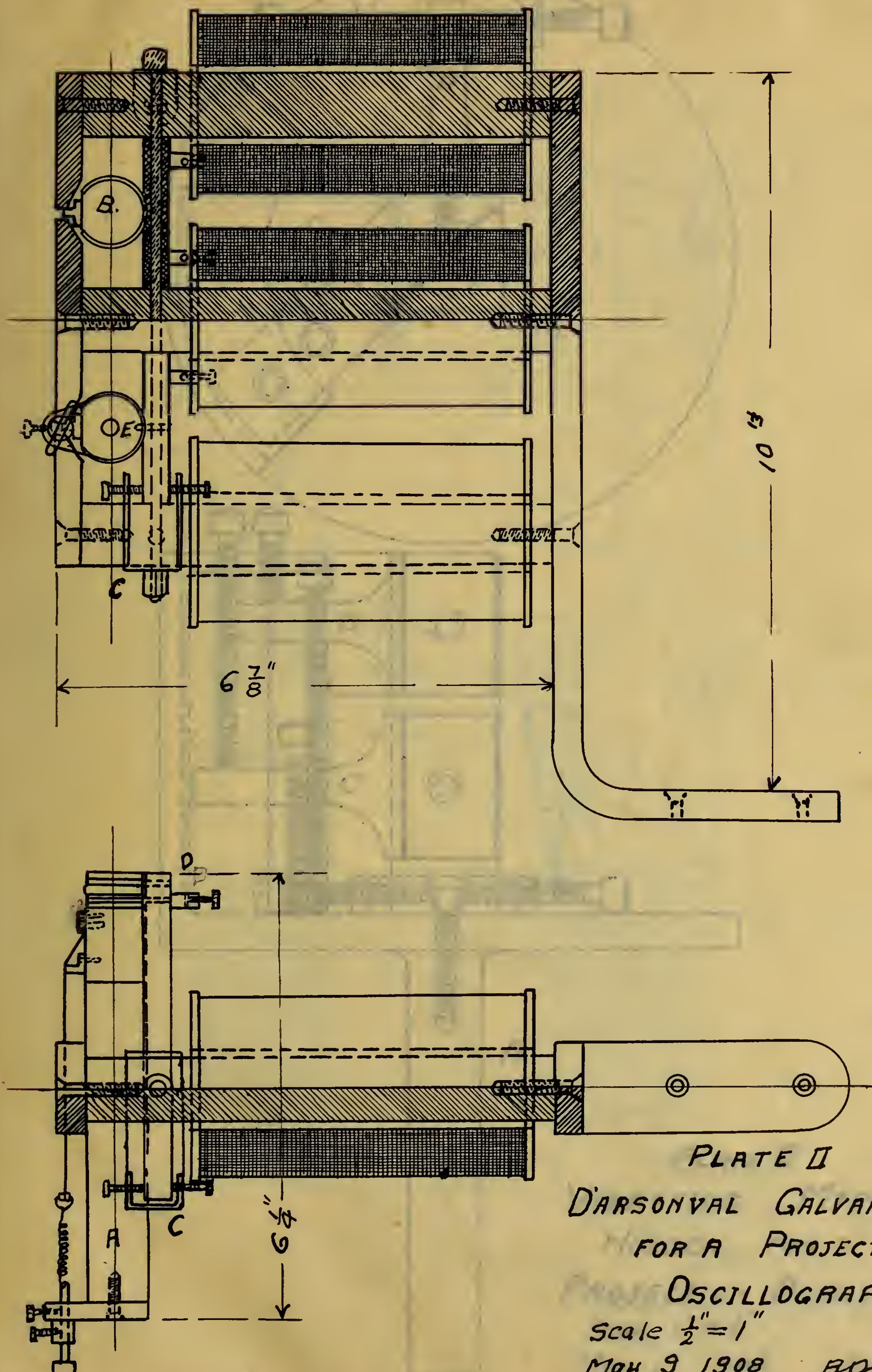

PLATE II
D'ARSONVAL GALVANOMETER FOR A PROJECTION OSCILLOGRAPH
Scale 1/2" = 1"
May 9 1908 B.O.Brown

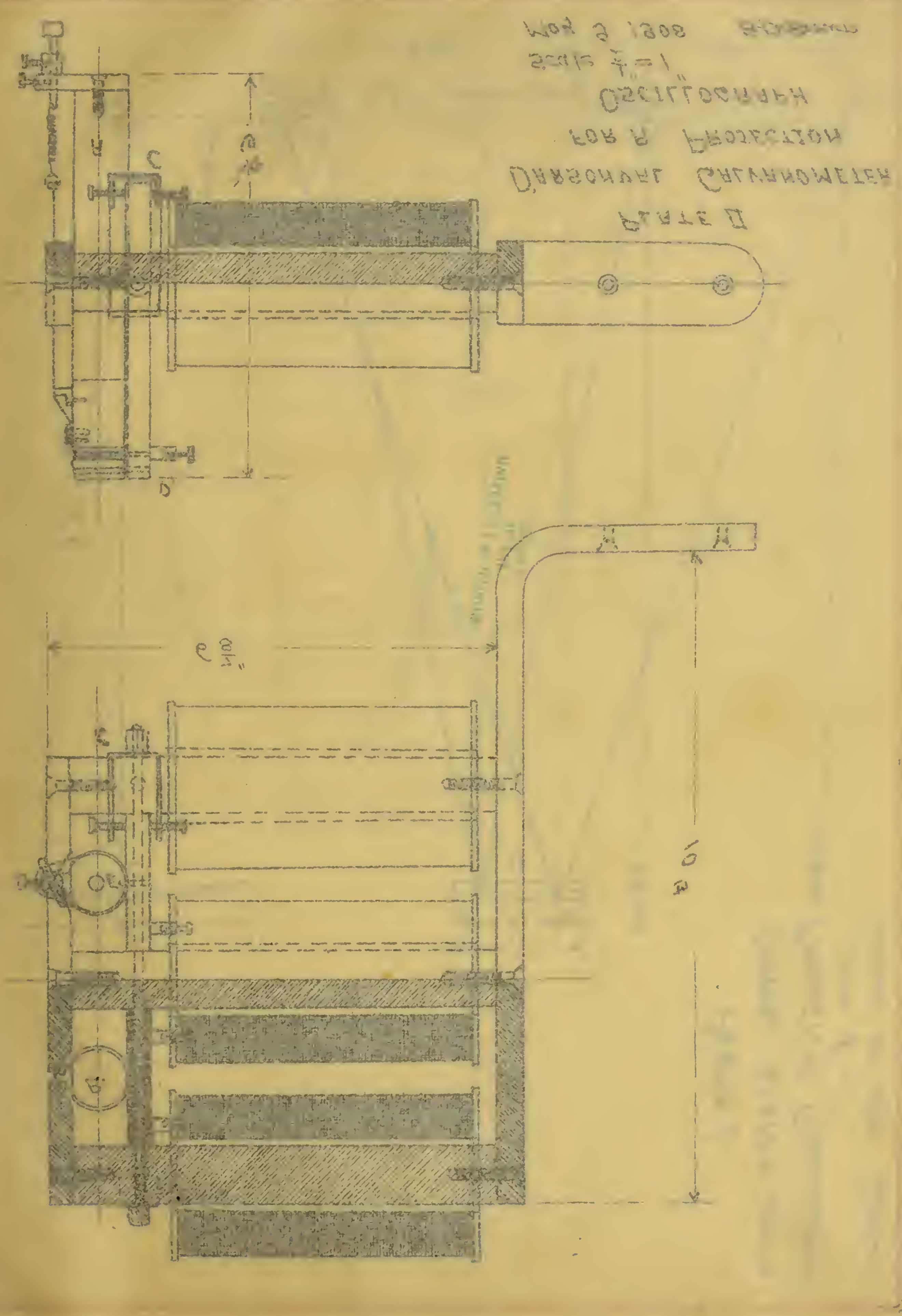
Plate II
D'Arsonval Galvanometer
for a Projection
Oscillograph
Scale $\frac{1}{2}'' = 1''$
May 9 1908
C
D
A
$6\frac{13}{16}''$

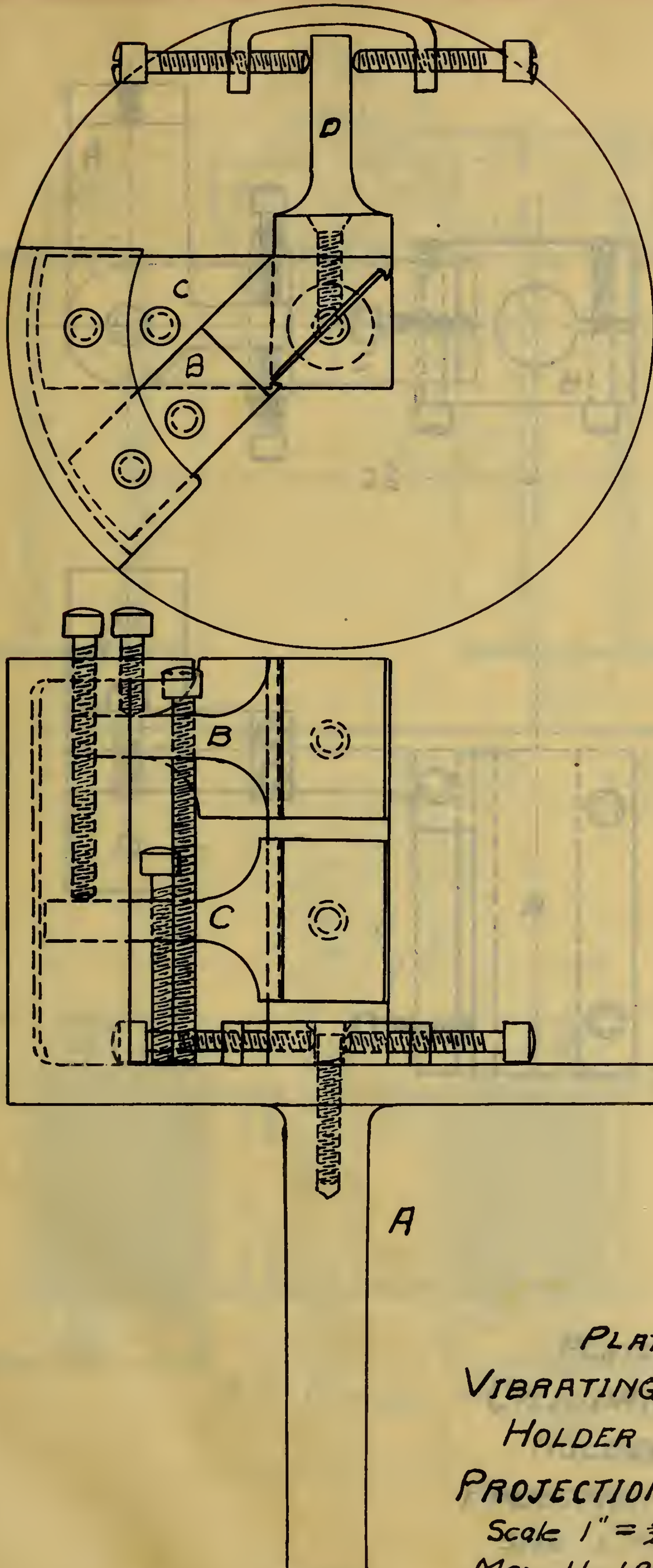

PLATE III

VIBRATING MIROR
HOLDER FOR A
PROJECTION OSCILLOGRAPH

Scale 1" = 1/2"

May 11 1908 B.O.Brown

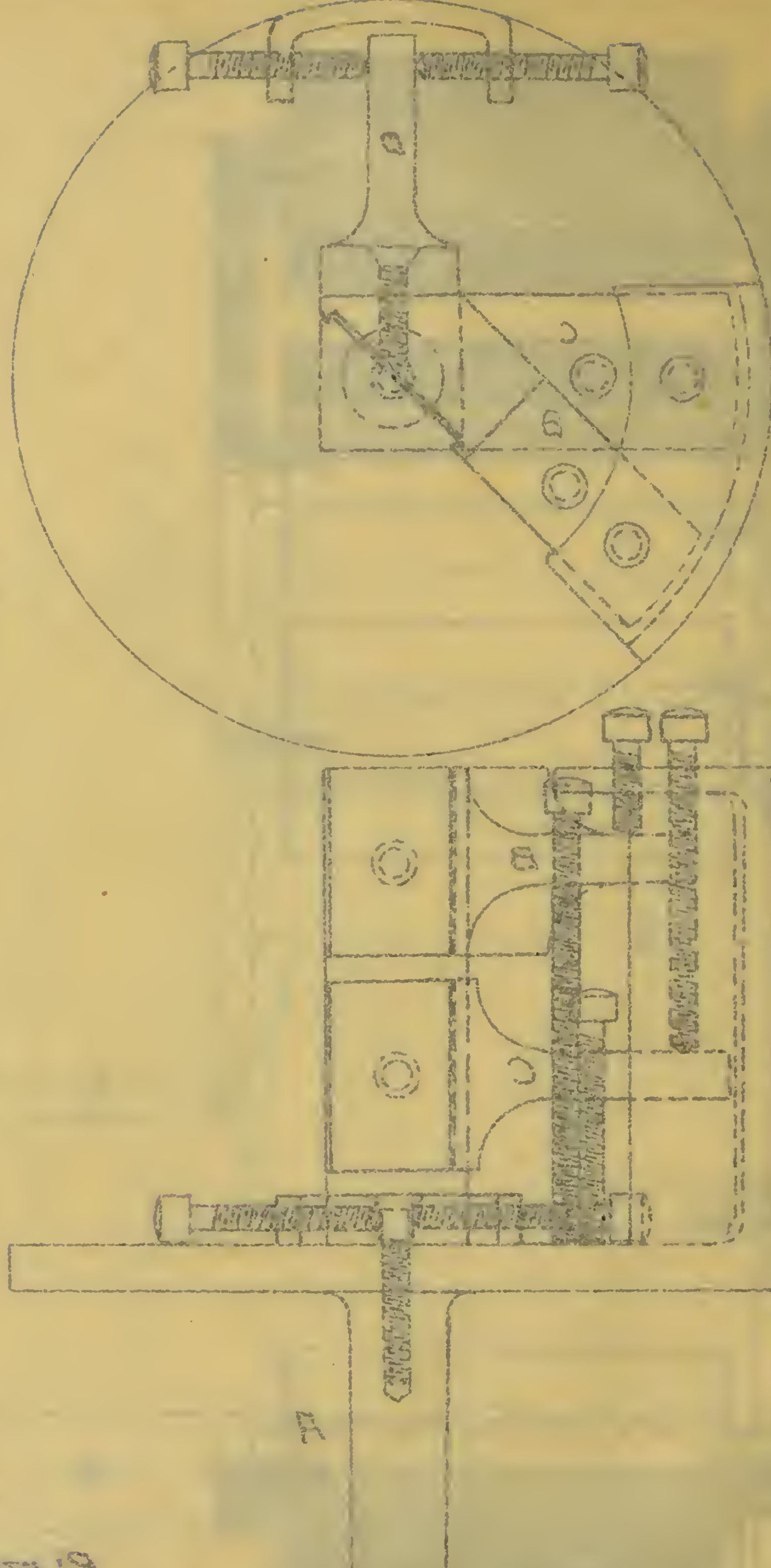

Plate III

Vibrating Mirror

Holder for a

Projection Oscillograph

Scale 1" = $\frac{1}{2}$"

May 11 1909 [illegible]

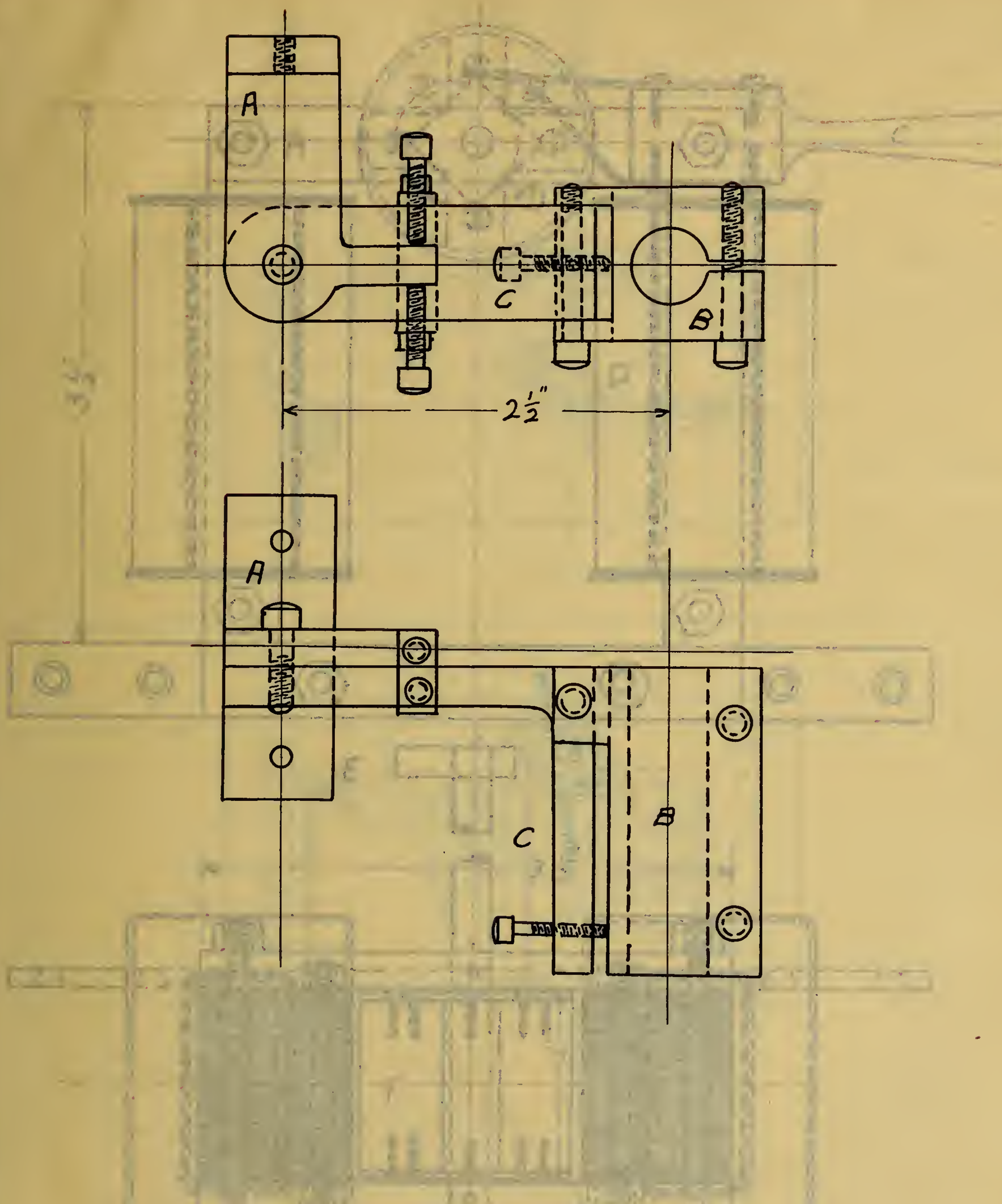

PLATE IV
CYLINDRICAL MIRROR
HOLDER FOR A
PROJECTION OSCILLOGRAPH
Scale 1" = 1"
May 12 1908
B.O. Brown

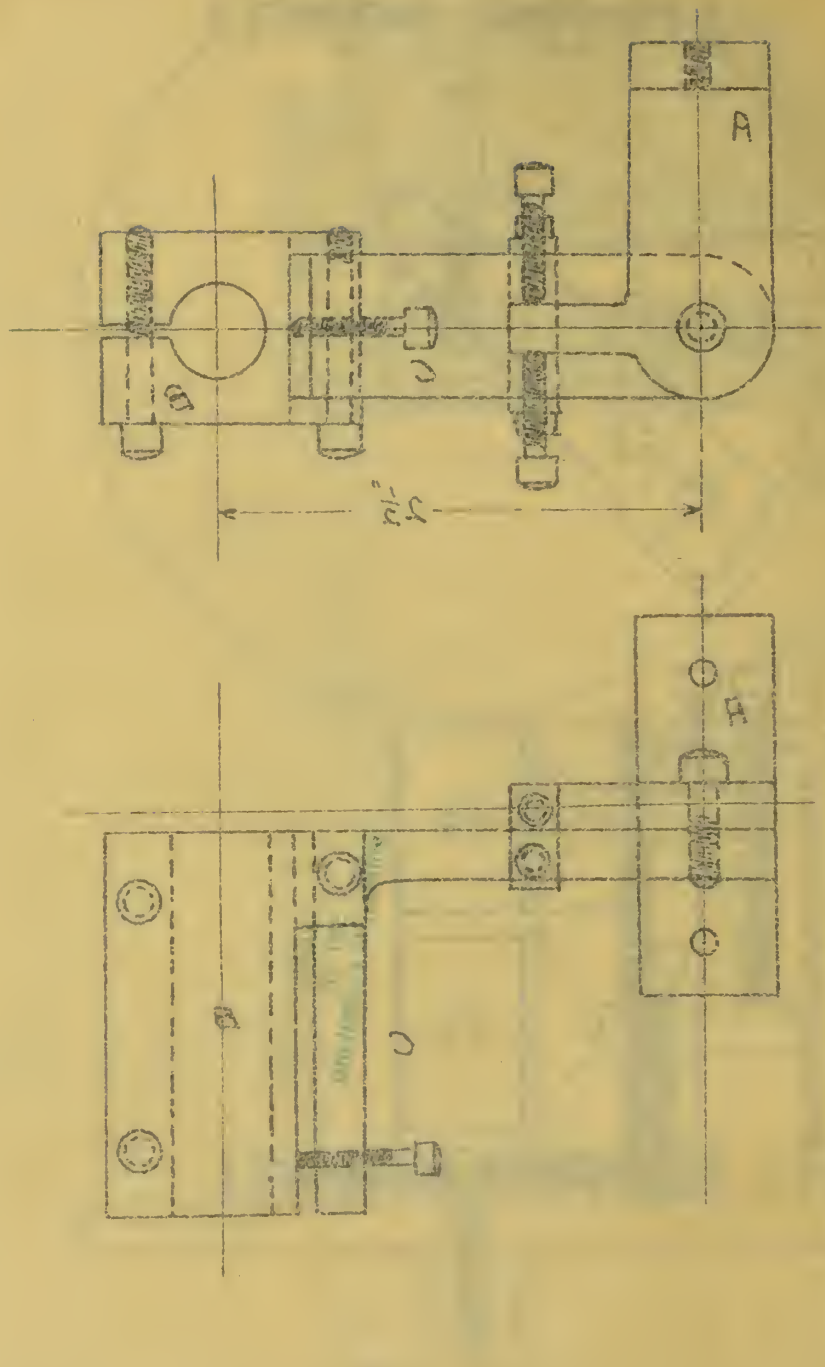

PLATE IV
Cylindrical Mirror
Holder for a
Projection Oscillograph
Scale 1" = 1"
May 12 19[illegible] [illegible] Brown

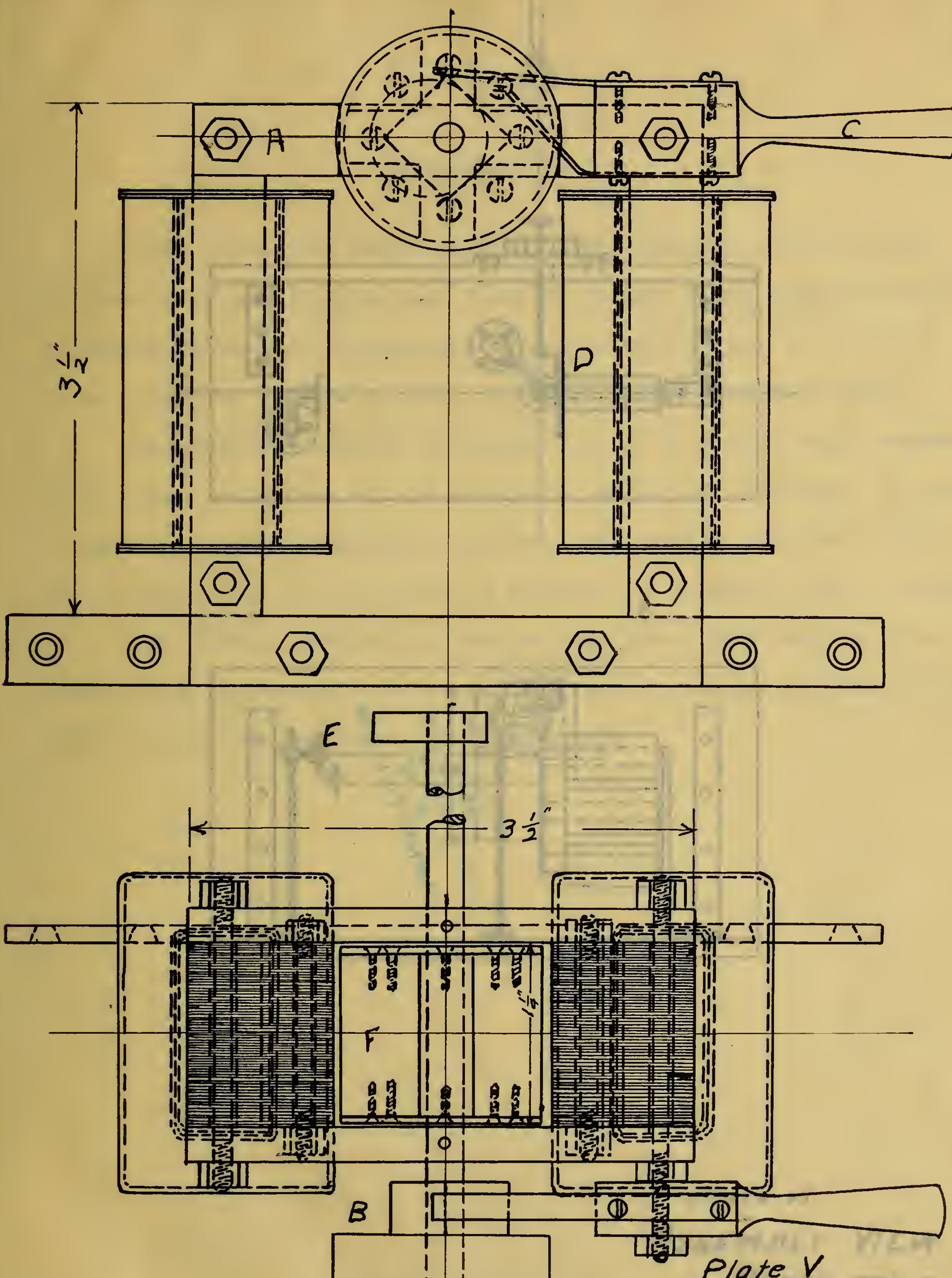

Plate V
Sychronous Motor For a
Projection Oscillograph
Scale 1" = 1"
May 9 1908 B.O. Brown

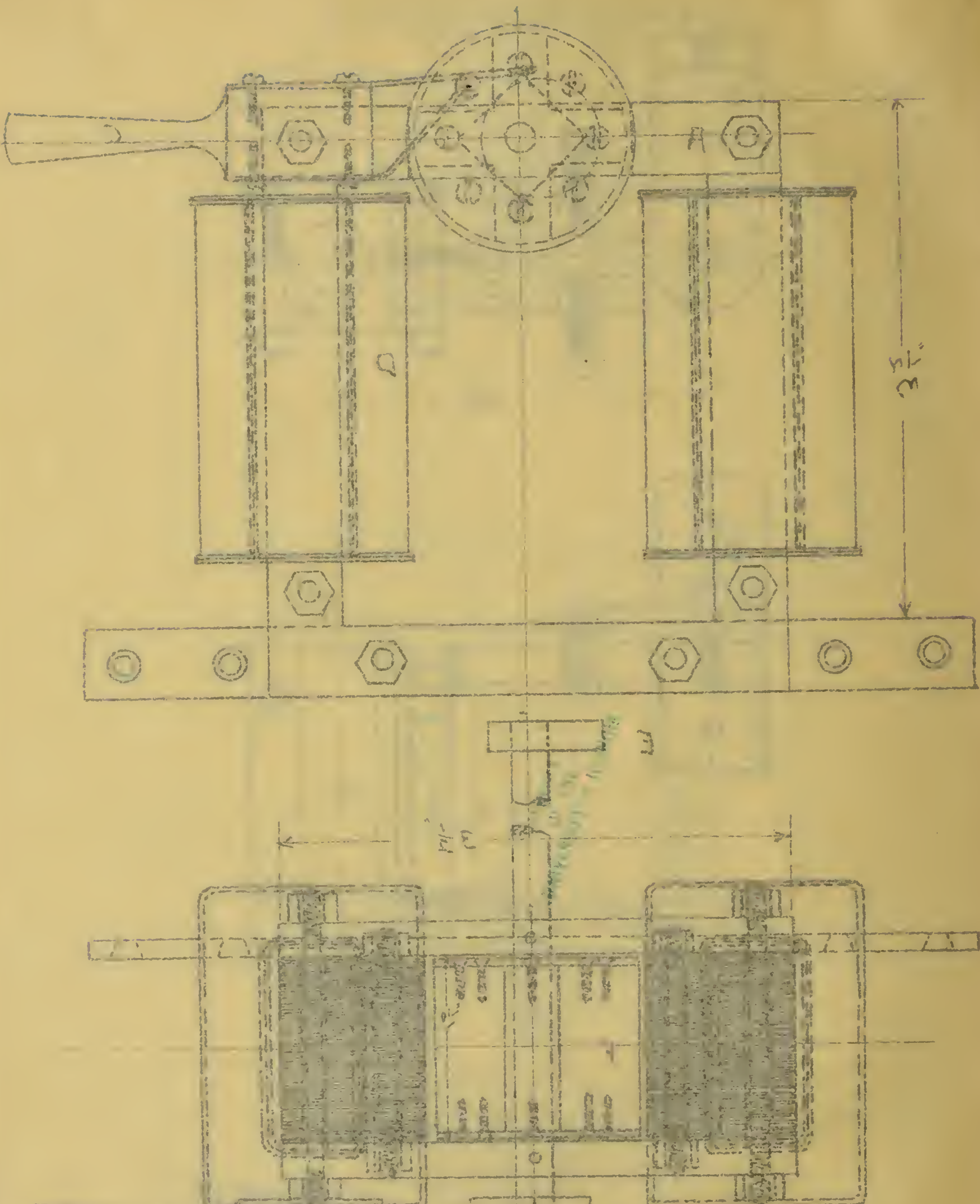

Plate V

Synchronous Motor For a Projection Oscillograph
Scale 1" = 1"
May 9 1928 S.O.Brown

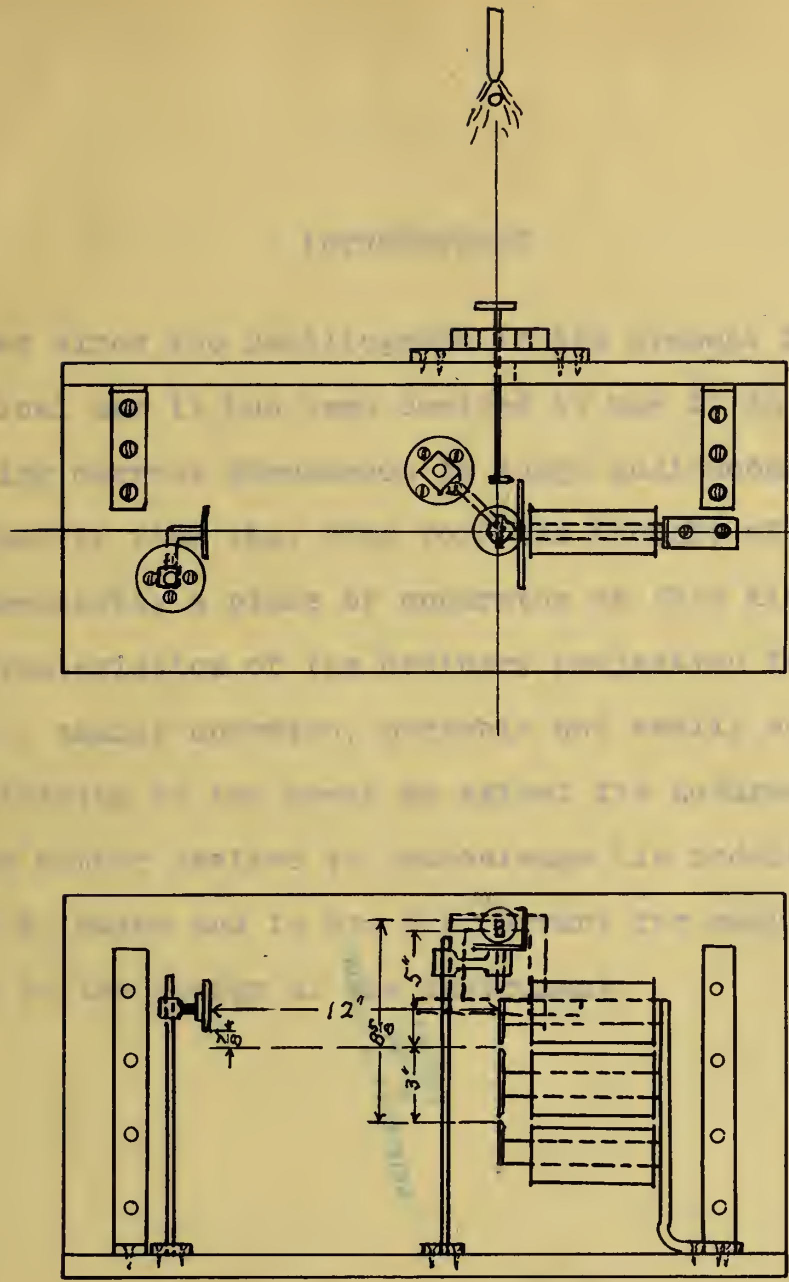

PLATE VI

ASSEMBLY VIEW
OF PARTS FOR A
PROJECTION OSCILLOGRAPH

Scale $\frac{1}{8}'' = 1''$

May 11, 1908 B.O. Brown.

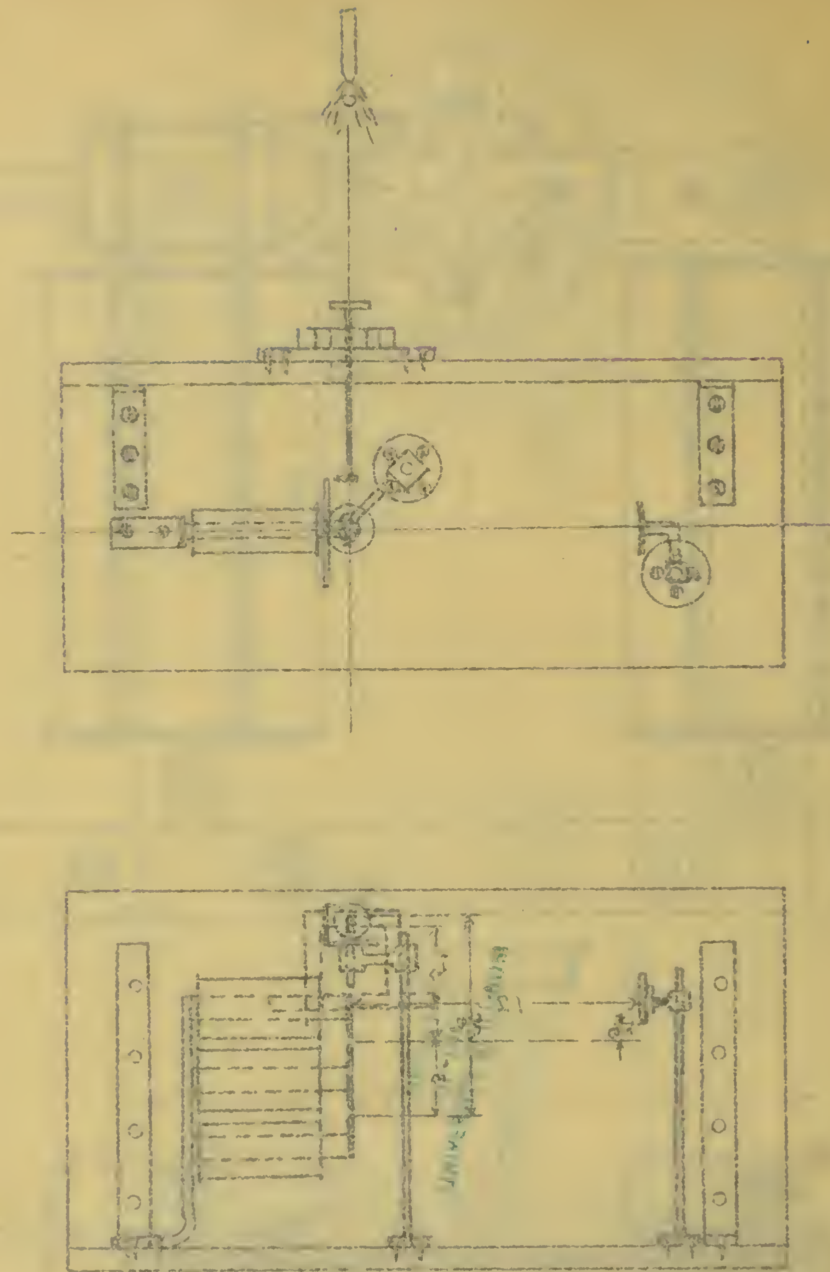

PLATE VI

ASSEMBLY VIEW

OF PARTS FOR A

PROJECTION OSCILLOGRAPH

Scale 3" = 1'

May 11, 1904

INTRODUCTION

Ever since the Oscillograph in its present form has been in practical use it has been desired to use it in demonstrating alternating current phenomenon to large audiences. It was with this object in view that this work was thought of and begun.

Necessarily a piece of apparatus of this kind must possess many characteristics of the ordinary projection lantern. It must be rigid , easily operated, portable and easily adjusted, without sacrificing to too great an extent its accuracy and delicacy.

The author desires to acknowledge his indebtness to Professor E.B. Paine and to Mr. J.M. Bryant for many valuable suggestions in the design of the instrument.

REFERENCES

The projection oscillograph must necessarly be much like the common form on the market at present. In these the images are either taken on a photographic film or can be observed by a single observer at a time. For description of these instruments the following references are given.

1. Scientific American Supplement, May 24, 1904, Recording Alternating Current wave forms by Duddell Oscillographs.

2. New York Electrical Review, Sept. 13, 1905, Description of the Blondel Oscillograph.

3. Robinson, Proceedings A.I.E.E. Vol. 24, April 1905, The Oscillograph and its Uses.

4. Duffy, Thesis, 1903 University of Illinois, The Oscillograph, Its Construction and Uses.

5. Scientific American June 1903, The Duddell Portable Oscillograph.

6. Wheeler and Akers, Thesis 1905 University of Illinois, The construction and operation of an oscillograph of the D'Arsonval type.

7. Crauford, Electrical Age, Nov. 1907, An Oscillograph for Demonstration and testing purposes.

8. Institution of Electrical Engineers, October 1907, Hot wire Wattmeters and Oscillographs.

THE DESIGN

In the present design it was decided to retain the D'Arsonval Galvanometer principle, but to depart from the previous designs in the optical system.

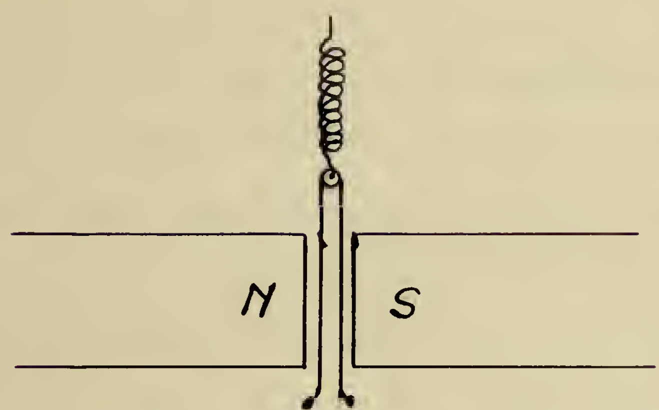

Fig. 1

The principle of the galvanometer is best understood by reference to fig. 1. This consists of two fine strips of phosphor bronze ribbon bent over a small pully and held by it in tension by a coiled spring, the two free ends being connected to a source of alternating current. These are supported between the poles of a powerful electro-magnet. If alternating current is sent thru these strips one will be forced backward and the other forward for one instant then as the current changes, the action will be reversed and the mirror will vibrate as the current passing thru it. If light shines on the mirror from a point source and is reflected on a screen, the reflection will not be a point but a line; due to the vibration. If this line of light is again reflected by a second mirror which vibrates at right angles to the first but in synchronism with it, then the reflection will not be a straight line but one or more sine

Curves.

Theoretically it makes no difference which of the vibrations occur first but practically it does for the galvanometer mirrors must be small, often less than .01 sq. inches, hence it is easier for the first vibration to be given by the galvanometer and this is the practice in the instruments on the market. This has the disadvantage that the minute quantity of light comming from so small a mirror must be reflected at least once more and often twice, which means that, for ordinary reflecting surfaces, not more than 50 to 25% of the light is utilized.

With the idea that if the reflection from the small galvanometer mirror were the last one before striking the screen there would be enough light to show the curve, the following optical system was designed.

Two views of the optical system are shown in Plate I, the upper view being from above and the lower one from one side. Light comes from an electric arc in parallel rays, strikes the mirror V and G' and G". No matter what part of the cylindrical mirror the light strikes it will be reflected in a horizontal plane so as to strike G' or G". If two galvanometer mirrors are required then it is only necessary to put in two mirrors at V and have them at slightly different angles to the vertical or center line, then they can be adjusted so that light from one will always strike G' and, from the other G".

V' and V" are, when properly adjusted, rigedly fastened together and made to vibrate in a horizontal plane by a synchronous motor so that the light beams pass from one edge of the

cylindrical mirror C to the other making two lines of light on it instead of two points, these being horizontal lines and, if the galvanometer mirrors are stationary, would appear on the screen as two horizontal lines. If the galvanometer mirrors are caused to vibrate in a vertical plane by the passing of alternating current, as before described; then the light beams will no longer trace a straight horizontal line but a sine curve depending upon the vibration of the galvanometer coil. With such an optical system all mirrors must be capable of very close adjustment. In this system there are three reflections which is the number found in the instruments on the market. To maintain this low number of reflections and have the arc light in a horizontal position, the galvanometer coils must be horizontal also. This necessitates the galvanometer design taking the form shown in Plate II.

The drawing in this plate is 1/2 size. The two galvanometers are combined into one instrument so as to make the assembling easier and more rigid.

Several experiments were tried to determine the smallest rigid mirror that could be used and still give a large enuugh quantity of light. These experiments consisted of taking a thin mirror and covering it over with a black paper all but the size of mirror to be tested, then reflecting the light from an arc onto a screen by means of the small uncovered part of the mirror. In this way the size of mirror was determined to be about one eighth inch square.

Since the mirror must vibrate between the pole pieces the

air gap was fixed as 3/16 of an inch for each magnetic circuit. Assuming a flux density of 40,000 lines per square inch in the air gap this would give 40,000 X .3133 X .1875 = 2300 ampere turns to force the required flux thru the air gap. From a rough calculation the ampere turns required for the iron circuit is 200 thus making a total of 2500 ampere turns for each circuit or 5000 ampere turns in all. This was divided between three coils thus making 1667 ampere turns per coil. Since the current would not be on for a long time, No 20 B. and S. gage wire was calculated to carry one ampere safely thus making 1667 turns of wire on each coil, of No 20.B. and S. gage wire.

The distance between centers of the galvanometer mirrors had already been set as 3 inches so the coils had to be designed to fit that space. Making the core 1 inch cylindrical, this leaves the depth of coil possible as 1 inch including insulation and spool. A length of 4 1/2 inches was chosen and the depth of wire found to 5/8 of an inch. Allowing 3/8 of an inch on the diameter as inside clearance and insulation there remains an outside clearance of 3/8 of an inch between the spools which is desirable.

The magnetic circuit with other details is shown in Plate II. The part forming the back to be bent at right angles so as to form a support or base to the galvanometer. The pole pieces were to be cut from soft iron 1 1/4 inches wide by 3/8 inches thick except at the tip which was made 1/8 inch cutting back at an angle of 60°. The galvanometer coil is mounted on a cylinder of hard rubber shown at A 15/16 inches in diameter and 6 inches

in length. A flat surface is cut out of this so as to be 5/8 of an inch in width, this giving a place to fasten the coil and connections. The phosphor bronze strips are fastened at one end by clamping to a fuse by a small hard rubber block tightened by a 2 - 56 machine screw screwing into the cylinder. The other end is fastened by looping over a small hard rubber pulley being supported by a small coiled spring about 1 inch long fastened as shown in the drawing so that the tension could be varied and also the coil turned so a to adjust the mirror in one plane. Electric connection is made with the coil strips by fastening them thru the fuses to two seperately insulated brass rings on the end of cylinder A. The rings are turned to a diameter slightly less than the cylinder A so that the spring contact will serve as a stop when it is in the proper position. By having the galvanometer coil thus arranged it can always be easily removed and is complete within itself. The cylinder of hard rubber is held in place by means of a brass tubing with the side next the air gap cut away the same as the hard rubber cylinder. This is a piece of 1 inch brass tubing 1/32 inch thick and three inches long for each holder. This should have just enough spring in it to make the hard rubber fit snugly without being fastened. The brass holder is fastened to a piece of hard rubber 2 1/8 inches wide by 4 1/2 inches long and 3/8 inches thick. Each holder is fastened to the hard rubber by two small countersunk machine screws screwing into the hard rubber. These hard rubber supports are pivoted by a 1/8 inch brass rod running thru them and the magnet cores so that they are held fast in a vertical plane at

a fixed distance from the air gap, but turn about the pivot in a horizontal plane. This is so as to adjust the mirrors to bring the ray of light to the same zero position on the screen. The adjustment is arranged to be made by 2, 3-48 machine screws one on either side of the hard rubber block for each block. These screws screwing into a brass stirrup comming out from the core pieces. The lower stirrup is shown at C and C, but the upper one is not shown on Plate II. Contact is made on the rings of the cylinder A by two springs made of No. 10 spring brass wire being bent similar to B so that each one engages the proper ring when the cylinder A is slipped in place. These springs are connected to binding posts on the back of the hard rubber block as shown at D, there being two binding posts on each side of the hard rubber block. In order that the coil will always be placed in the holder in the proper position a small groove is cut the full length of the cylinder in the back which passes over a pin as at E.

Standard machine screws were used in all construction of the galvanometer, brass ones being used except where they screwed into iron, then iron machine screws.

THE VIBRATING MIRRORS

One vibrating mirror for each galvanometer coil was found to be needed from the design of the optical system. Careful adjustment was also required so that a holder for the mirrors had to be designed that would admit of their careful adjustment. Each mirror in made one half inch square. They are to vibrate in synchronism so that they are fastened to the same support as shown in Plate III. This drawing is made twice full size so as to bring out the details. The main support is made as shown and merely serves as a housing for the other parts. The stern of it is fitted into a vertical bearing (not shown in the figure) which is in turn supported from the same base as the galvanometer by a vertical support. On the stem below the support a small arm is securely fastened so as to make contact with an eccentric on the shaft of the synchronous motor. The arm being held against the eccentric by a strong spring.

The mirror holders themselves are made of brass as shown at B and C. They are made at an angle with one another so as to give room for adjusting screws. These pieces are both fastened to the same suppot by means of small screws at a single point thus making a pivot so that the beam of light could be moved in a vertical plane. Each halder is made seperate so that the movement of the vertical plane is independent. The support D can be moved in the horizontal plane and this moves the mirrors together in that plane. This is all that is necessary since the mirrors are to reflect their light both in the same plane and when one is in position the other must be in the same horizontal

position. The holders B and C are adjusted by tightening one screw and loosening the other. The screw that threads thru the upper support of A presses against the holder B or C and the screw that threads thru B and C presses against the housing A. By making these screws tight there is no danger of them working loose due to the vibration. The support is also make to be adjusted by tightening one screw and loosening the other, but in this case both screws are threaded thru a part of the housing and pressed one on either side of the support. The support is pivoted at the center of the housing by a machine screw passing into the housing.

THE CYLINDRICAL MIRROR AND HOLDER

The cylindrical mirror is designed with a radius of twelve inches, and to give a large enough wave to be seen under ordinary conditions it had to be an arc of 4 inches and 2 inches high.

In order to get the proper adjustment of the light beam on the galvanometer mirror the holder with the adjustments as shown in Plate IV were designed. The mirror is made to be held by a brass back which would screw into the piece A by 2 machine screws. The piece A was made from a piece of T iron and was pivoted so as to be adjustable as shown; by means of two machine screws similar to those on the vibrating mirror. In order to get the center line of the mirror to coincide with the center line of the vibrating mirror and galvanometer mirror a second adjustment is necessary. This is shown at C which is an L piece with an adjusting screw at one end and the T piece at the other pivoted at the apex of the angle. This is pivoted to a block B which is made to be clamped on a supporting rod as shown by the hole thru it. The rod is not shown but is supported from the same base as the galvanometer and mirror support.

THE SYNCHRONOUS MOTOR

The synchronous motor was taken from the general design of the motor used on the Oscillograph of the General Electric Co.

The synchronous motor was designed and constructed as shown in Plate V. It consists of a stator A, built up of transformer iron with two coils connected in series. They are wound with No 20 B and S gage and have approximately 800 turns per coil. The rotor consists of a cylinder of good quality steel milled out so as to make a cross making four poles when the machine is running. The part milled out is filled in by hard rubber which is held in place by two brass end plates, and machine screws. This is to prevent friction loss due to windage if the space were left open.

Since it is to be a single phase motor a starting devise is necessary. This is shown at B and C which is a four point cam that breaks the circuit each time a pole crosses opposite the pole of the stator. This devise is only necessary on starting and the circuit remains complete after synchronous speed is obtained by simply dropping the handle of the contact maker. Combined with the cam is a small flywheel to help the rotor keep constant speed. On the other end of the shaft is the eccentic for operating the vibrating mirror. Between the two is a semicircular disc that cuts off half the light from the electric arc to the vibrating mirror each revolution. This is not shown in the figure. This is necessary so as not to have the wave repeated in a reverse direction while the vibrating mirror returns to its initial position.

ASSEMBLY

The mirrors are being made by Bausch and Lomb of Rochester New York at the time this is written. Since the assemblying has not yet been done, the assembled parts are shown in Plate VI. No attempt is made in showing details which are already given. Only the relative positions of the different parts are accurately given in this plate. The base is to be 12 inches wide by 30 inches long with the galvanometer mounted on one end and facing along the base. Facing the galvanometer, a side is placed on the base its full length and 15 inches high. The vibrating mirrors are mounted so as to be in line with the galvanometer mirrors and vertically over them. The cylindrical mirror should be mounted directly in front of the galvanometer so that the horizontal distance from one reflecting surface to the other is 12 inches. The synchronous motor is now mounted on the side of the base, high enough up that the eccentric will make contact with the arm of the vibrating system. A 1 1/4 inch hole is then bored thru the side in a horizontal line with the two mirrors so that light comming from an electric arc will strike them squarely.

All that remains now is to adjust the mirrors and the instrument is ready to work the same as an oscillograph of the ordinary type.

ADJUSTMENT OF MIRRORS

The first adjustment is to move the vibrating mirror up or down until the center of the lower mirror is just five inches from the center of the upper galvanometer mirror. Next move the cylindrical mirror up or down until its center is one and seven eighths inches above the center of the upper galvanometer mirror.

With the light falling centrally on the vibrating mirrors, → adjust the two together so that the light falls on a vertical center line of the cylindrical mirror, being sure that the eccentric is in the mid position. Next, adjust each mirror seperately so that the light falls on a horizontal line thru the galvanometer mirror; the light from the upper vibrating mirror should strike the lower galvanometer mirror, and the lower vibrating mirror corresponds to the upper galvanometer mirror. If the light is not striking the galvanometer mirror on but one side of it, the cylindrical mirror should be adjusted till it does strike the mirrors. The light is now ready to be adjusted onto the screen. This is done by adjusting the two galvanometer mirrors until the two spots of light are as one. If the adjustments have been carefully made the instrument is ready for use and should require no further adjustment unless taken apart.

CONCLUSION

The author had hoped to include some tests of the instrument on this article, but because of the delay in receiving the mirrors it is impossible to do so.

So far as can be judged there is no reason why the instrument should not work satisfactorily. The main difficulty will be to get parallel light without too much absorption by the lens of the projection lantern. For the best results a 90° arc should be used with not more than two lenses between the arc and the vibrating mirrors. It would of course be best to use mirrors silvered on the surface rather than behind the glass, but the difficulty of keeping them from tarnishing is objectionable.